Special reprint from Kunststoffe international 10/2013

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Start of a New Era

Fiber Composite Components

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Back seat part made of CFRPs before demolding (figure: Frimo)

Fiber Composite Components. Previously unknown possibilities in terms of quality, economy, ergonomy, and robust processes have been opened up by new approaches and solutions for the manufacture of fiber composite components on a series scale. Moreover, such components can also be designed with filigree or even bionic surface structures in future – also with in-mold painting.

Start of a New Era

ARMIN DANIEL

During a meeting of experts from tooling and equipment specialist Frimo in Lotte, Germany, and from the chemical company Huntsman Polyurethanes in Everberg, Belgium, the latest technologies and trends in the polyurethane processing industry were discussed, as well as established developments and production methods for fiber composite components (**Title figure**). With new approaches, both on the chemical and on the machine side, more efficient and more robust production possibilities are to be implemented in future. Primarily, suitable possibilities for high-volume production of (large carbon) fiber composite components are to be worked out. In 2011, Frimo and Huntsman signed a corresponding cooperation agreement.

Technical challenges for the production of fiber composite components are numerous, and mainly based on the facts that

- the components to be produced are usually just a few millimeters (about 2 mm) thick, but can be three-dimensional and laminar (up to more than 2 m²),
- on average, some 50 % of the components' volume must be filled with pre-formed, woven, and oriented fibers,
- mostly, the fabrics with oriented fibers have several layers that may not become displaced during mold filling,
- the inserted pre-formed fiber fabric must be enveloped completely and void-free by a matrix material,
- as component parts of a body shell, the items to be produced must be able to pass through the automakers' existing painting lines.

Translated from Kunststoffe 10/2013, pp. 234–237
Article as PDF-File at www.kunststoffe-international.com; Document Number: PE111505

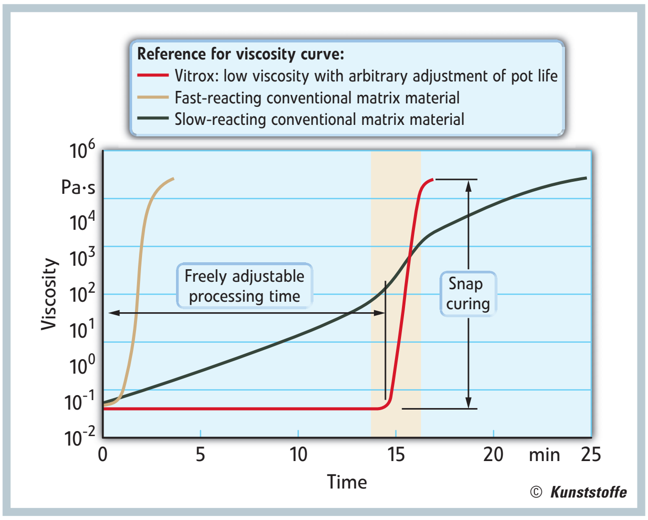

Fig. 1. Viscosity curve of conventional PU systems compared with Vitrox (figure: Huntsman)

Such components are mainly produced by inserting the fiber fabric and injecting the matrix material into the closed mold.

Other established processes, in which fiber composite components are manufactured by spraying the matrix material into the open mold, or by injection into molds that are opened with a small parallel or angled gap, are suitable for individual applications, but soon reach their limits with large and possibly three-dimensional components.

Well-known matrix materials start their reaction immediately after being admixed, i. e. to increase their viscosity. This

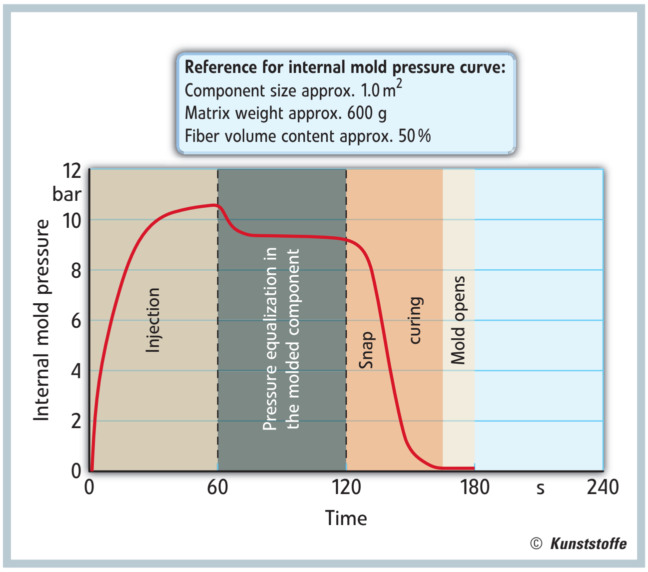

Fig. 2. Curve of the internal mold pressure: Even with a long pot life, short cycle times are achieved through snap curing (figure: Huntsman)

happens all the faster, the shorter the component's demolding time is to be.

Flow Resistance Determines Process and Quality

The flow resistance in the mold during injection is particularly critical for the process and the quality of the components. The flow resistance in the mold – which is already problematic because of the progressing filling level – grows disproportionately due to the increasing viscosity of the mixed material. The higher the flow resistance, the greater is the risk that the fiber fabric will become displaced during injection.

In addition, multi-layer fiber fabrics can only be enveloped completely and void-free by the matrix material up to a certain viscosity. To enable laminar parts to be produced at all, the time-based viscosity curve and throughput of the mixture must be adapted continuously, in order to keep the flow resistance below the max. permissible limit.

Flow resistances of more than 150 bar occur in today's production processes. Consequently, molds for components with projected surface areas of less than two square meters require clamping forces of more than 3000 tons to ensure that the mold remains closed during injection. Such clamping forces can only be provided by large presses – preferably installed as stationary production plants.

Today, normal production cycles for components with a surface of about 1,5 m^2 lie between 20 and 30 minutes per press or production unit. This means that for the production of e.g. 300 components per day (press equivalents) in two-shift operation, eight to twelve presses must be purchased. For mass production of about 1,200 vehicles per day, this involves 30 to 45 presses for the two-shift model.

It is difficult to imagine that such production concepts, which are exclusively and essentially specified by present-day processing requirements, will become established for series production in future:

- The necessary investments seem to be very high,
- the process itself is technically very demanding, and possibly even unstable due to many relevant parameters,
- an optimum design for workplaces is not possible with mold halves that can only be opened in parallel,
- mobile production concepts (such as rotary tables or Frimo's proprietary PURe Track and PURe Floor conveying units with individually powered mold carriers, etc.) to assist the decoupling of individual processing steps, and almost essential for high volume production, cannot be represented in a technically and economically feasible manner.

All the listed shortcomings of the production technologies available today can be eliminated. Within the scope of the cooperation between Frimo and Huntsman, entirely new solutions have been developed to make this process economic and technically robust.

Pioneering Development – Constant and Low Viscosity

A new matrix material for enveloping the fibers in the closed mold has been developed by Huntsman, which has a low viscosity (less than 100 mPas) and keeps this value constant after being admixed **(Fig. 1)**. Chemically, the duration is arbitrary – and is therefore optimally adjustable for every production process. When this chemically adjustable pot life has elapsed, the polyurethane system (trade name Vitrox) reacts in the shortest time – almost instantaneously.

This opens up two important, previously non-existent, new processing possibilities:

Every component with any fiber volume content can be filled with optimum output performance. Ideally, the correspondingly required flow resistance should not exceed about 10 bar **(Fig. 2)**.

In spite of the practically unlimited injection time, the material reacts very quickly (snap curing) when the individually adjusted chemical time has elapsed. Even laminar parts can now be produced

Fig. 3. Mold carrier for evaluating RTM components with Vitrox in the pilot plant. The picture sequence shows important swiveling functions (figure: Frimo)

with relatively low clamping forces and short cycle times.

Mold Carrier instead of a Press

Even for the production of laminar fiber composite components, these new processing possibilities permit the use of mold carriers – as are also in standard use for mass production in other polyurethane processing industries **(Fig. 3)**. This results in significant technical and economic advantages regarding ergonomy as well as the processing and production technology:

If necessary, both mold halves can be tilted into the best position for any ergonomic or processing requirement, and all mold carriers can be placed in the optimum position for processing (e.g. to support injection and the envelopment of the fibers), enabling them to be integrated into any mobile manufacturing concept. Hereby, the proprietary conveyor systems PURe Track and PURe Floor with individually powered and maneuverable mold carriers seem to be particularly suited for high-volume production

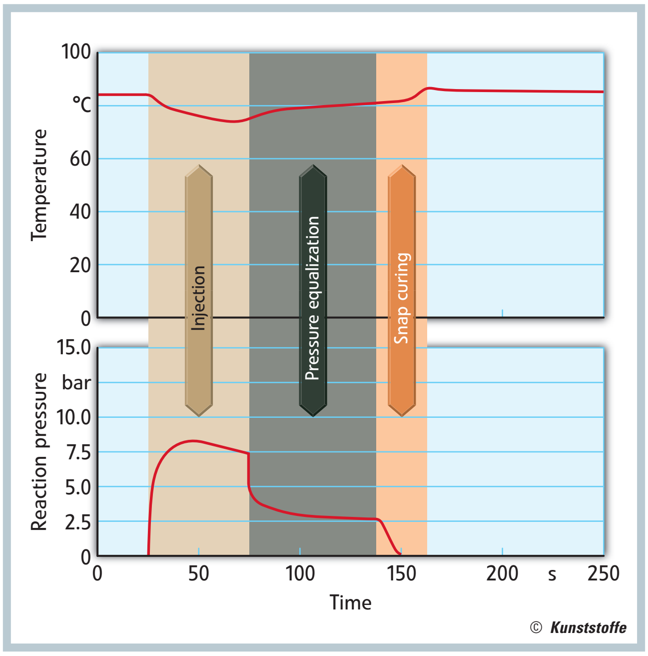

Fig. 4. Internal mold pressure and temperature curves near the runner for a composite fiber component. Matrix weight about 700 g, dosing rate about 15 g/s, internal mold pressure max. 8,3 bar (figure: Huntsman)

Fig. 5. Ultra precise, high-pressure two-component dosing machine as required for the pilot plant, and adapted to the processing of Vitrox (figure: Frimo)

The production process with Vitrox runs optimally at relatively low temperatures (about 80 °C on average) and practically isothermal **(Fig. 4)**. This enables another frequent disadvantage of previous systems to be eliminated: Standard tempering units for raw material and mold can be used. Expensive pressurized technologies, using oil as heat transfer medium, or even the need for fast mold heat-up by means of induction as well as fast cooling, are no longer required.

This new raw material also allows glass transition temperatures above 280 °C – an important and interesting possibility for in-line lacquering, particularly for the automotive industry. All other physical data are similar to those of well-known raw materials. Injection of the non-corrosive material is carried out by means of ultra-precision high-pressure equipment from Frimo's PURe Mix dosing machine range that is specially adapted to the process **(Fig. 5)**.

Apart from the new possibilities for technically stable and reproducible series production of fiber composite components, the low flow resistances and speeds also open up entirely new possibilities regarding the design of component surfaces.

Shark Skin Bionic Surfaces

Even the creation of bionic surfaces, like the reproduction of serrated shark skin platelets, has already been achieved, and is suitable for reducing the flow resistance of e.g. vehicles, ships, high-speed trains, or aircraft.

For the first time, these, and other precise reproductions of bionic surfaces, such as application of the lotus effect against contamination etc. are now possible for series production with fiber composite components – including laminar.

Thanks to the low flow speeds during injection of the matrix material directly into the mold, also surface colors can be produced by lacquering the interior mold surfaces (in-mold painting), i.e. filigree surface structures are not clogged up by the subsequent application of paint.

Conclusions

Thanks to the new raw material and the resulting processing and production possibilities, entirely new potentials for the manufacture of fiber composite components are opened up. Reproducible and high-quality components can be implemented in technically robust and proven production concepts, and also in ergonomically and economically appropriate production plants.

Meanwhile, practically all of the statements made here have been confirmed and verified in Frimo and Huntsman pilot plants together with further technical data and tests, and also by several customers from the supplier industry, and by a well-known automaker. ■

THE AUTHOR

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